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GB 2328526 A   US 5727515 A   US 5720262 A

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(54) Abstract Title
Regulating pressure in a high pressure store

(57)   The store is supplied with a volume flow by a high pressure pump, and the pressure is regulated by adjusting both the volume flow output by the pump and the pressure in the store. A control deviation between the actual pressure in the store and the desired pressure is determined. From the control deviation a control difference for pressure adjustment in the store is determined so that, when the control deviation is small, a characteristic with non-linear sections 4 is set for the pressure adjustment. Similarly, from the control deviation a control difference for volume-flow adjustment of the high-pressure pump is determined, so that, when the control deviation is small, a characteristic with non-linear sections 3 is set for the volume-flow adjustment. Outside the small difference range (from -delta to delta), a linear characteristic is used. The high-pressure store may be used in a high pressure fuel injection system.
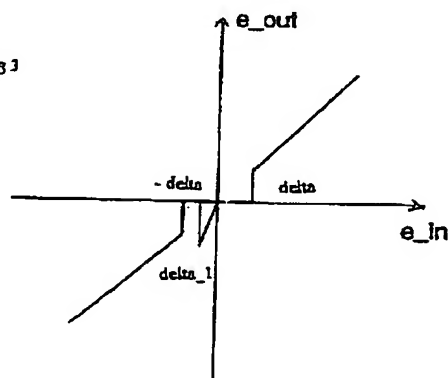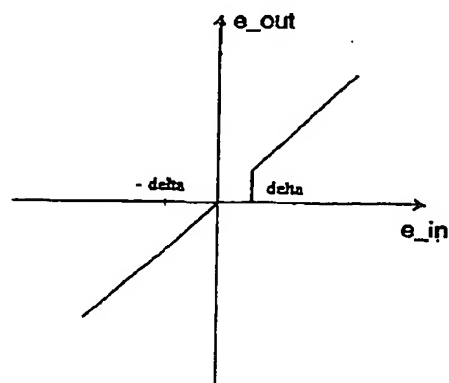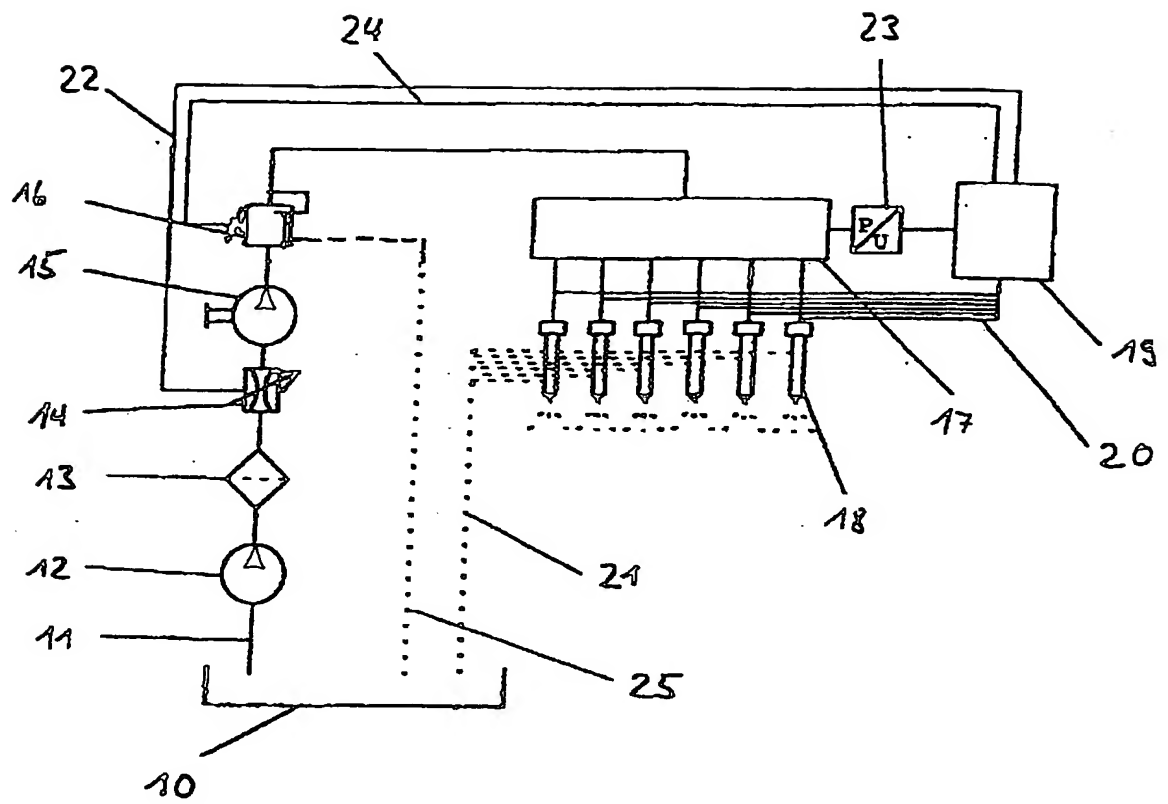
Fig 3

Fig 4

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At least one drawing originally filed was informal and the print reproduced here is taken from a later filed formal copy.
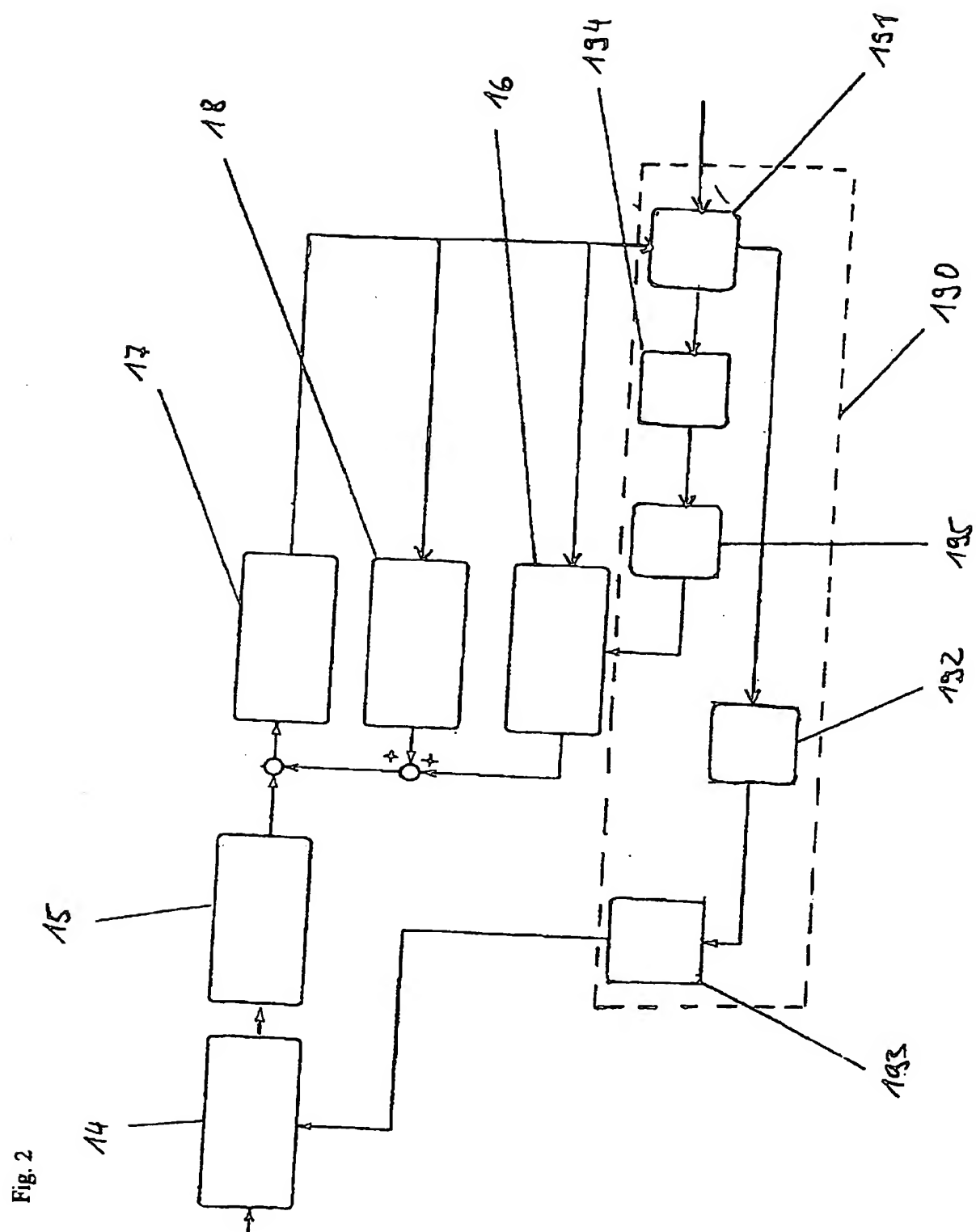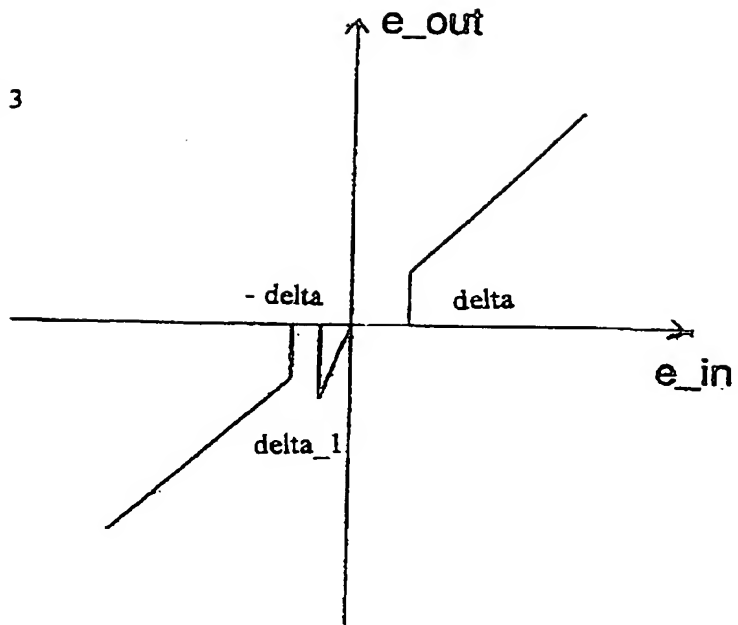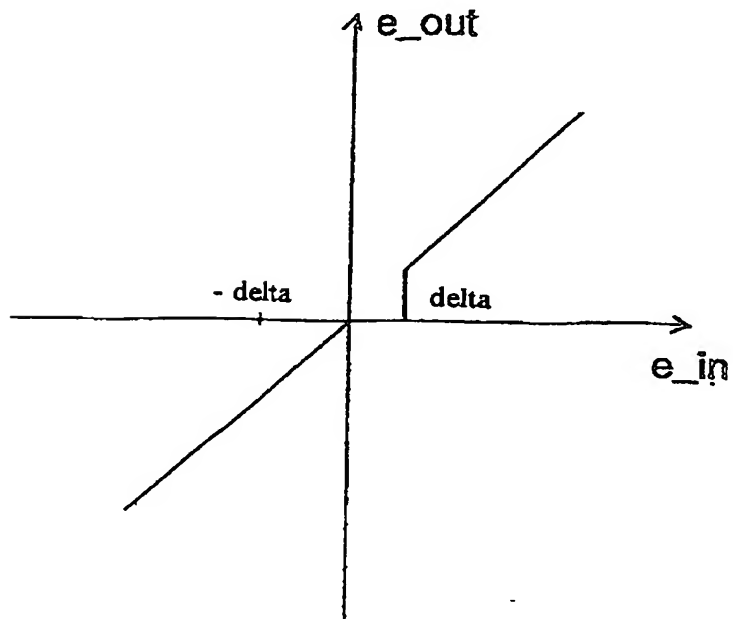
FIG.1

Fig. 2

Fig 3

Fig 4

METHOD AND ARRANGEMENT FOR REGULATING THE PRESSURE IN A HIGH-PRESSURE STORE

The invention relates to a method and an arrangement for regulating the pressure in a high-pressure store. A method and an arrangement for regulating a pressure in a high-pressure store, which is supplied with a volume flow by a high-pressure pump, in which the volume flow output by the high pressure pump to the high-pressure store are adjusted are known from DE 195 48 278 A1.

In the field of fuel-injection systems for internal combustion engines, priority has increasingly been given in recent years to high-pressure storage concepts in diesel engines and in Otto engines that make it possible to keep the injection pressure independent of the engine speed and the injection amount and furthermore to increase the average injection pressure to over 1600 bar. In such fuel-injection systems, the high-pressure pump, which is connected to a fuel storage tank, feeds fuel into the high-pressure store. The fuel, which is under high pressure in the high-pressure store, is then, by way of adapted line cross-sections, fed to injection valves which extend into the cylinders of the internal combustion engine. The injection processes in the cylinders are triggered by flow into the injection valves, the injection volume being dependent on the pressure at the injection valves and the duration of the flow.

In order that the pressure in the high-pressure store, which pressure determines the injection pressure into the cylinders, can be matched precisely and quickly to the desired pressure which corresponds to the desired operating condition of the internal combustion engine, the high-pressure store is connected to a control unit which ascertains the actual-pressure

value prevailing in the high-pressure store and
compares it with the desired-pressure value. From the
control deviation which is established, the control
unit determines a manipulated variable for a high-

5 pressure control element connected to the high-pressure
store. Surplus fuel, which is not required in order to
maintain the desired pressure in the high-pressure
store, is returned to the fuel storage tank by way of
the high-pressure control element. In order to

10 establish the manipulated variable of the high-pressure
control element, the control unit preferably has a
proportional-integral controller, PI controller for
short, which is distinguished by a fast response with
simultaneously high control quality.

15 In order to prevent the high-pressure pump
constantly feeding too much fuel into the high-pressure
store, which fuel then has to be removed again by way
of the high-pressure control element, a volume-flow
control element is arranged in the fuel supply line to

20 the high-pressure pump, in order that the fuel volume
flow to the high-pressure pump can be adjusted
according to need. In this connection, the control of
the volume-flow control element can take place by way
of a comparison of the volume flow delivered by the

25 high-pressure pump at that time with a desired volume
flow corresponding to the respective operating state of
the internal combustion engine, in order to determine
from the differential value, by means of a PI
controller, a manipulated variable for the volume-flow

30 control element. Such a control, however, necessitates
an additional measured-value detector for determining
the volume flow currently being delivered by the high-
pressure pump. Therefore, the volume-flow control
element is generally controlled with the aid of a

35 predetermined characteristics field. A disadvantage of
such a characteristics-field control, however, is that

the volume-flow control element has to be operated with a sufficient safety clearance with respect to the minimum possible volume flow, in order to prevent an under-supply of the high-pressure store with fuel by the high-pressure pump. This in turn leads to a worsening of the energy balance, because the high-pressure pump still compresses too much fuel and feeds it into the high-pressure store.

The present invention seeks to provide an improved method and an improved arrangement for regulating a pressure in a high-pressure store, which is supplied with a volume flow by a high-pressure pump.

According to a first aspect of the invention, there is provided a method for regulating a pressure in a high-pressure store, which is supplied with a volume flow by a high-pressure pump, wherein the volume flow output by the high-pressure pump to the high-pressure store and the pressure in the high-pressure store are adjusted, comprising the steps of:

determining a control deviation between an actual-pressure value detected in the high-pressure store and a predetermined desired-pressure value;

determining a control difference for a pressure adjustment in the high-pressure store from the control deviation which has been ascertained in the case of the pressure in the high-pressure store, wherein in the range of a small control deviation, a characteristic with non-linear sections between the control deviation and the control difference is set for the pressure adjustment; and

determining a control difference for the volume-flow adjustment of the high-pressure pump from the control deviation which has been ascertained in the case of the pressure in the high-pressure store, wherein in the range of a small control deviation, a characteristic with non-linear sections between the

control deviation and the control difference is set for the volume-flow adjustment.

According to a second aspect of the invention, there is provided an arrangement for regulating a pressure in a high-pressure store, which is supplied with a volume flow by a high-pressure pump, comprising

a volume-flow control element for adjusting the volume flow output by the high-pressure pump to the high-pressure store; and

a high-pressure control element for adjusting the pressure in the high-pressure store; and

a control device which has: a comparator for determining a control deviation between an actual-pressure value detected in the high-pressure store and a predetermined desired-pressure value;

a high-pressure regulator, which is connected to the comparator and the high-pressure control element, in order to determine a control difference for the pressure adjustment of the high-pressure control element from the control deviation ascertained by the comparator in the case of the pressure in the high-pressure store, wherein in the range of a small control deviation, a characteristic with non-linear sections between the control deviation and the control difference is set for the pressure adjustment; and

a volume-flow regulator, which is connected to the comparator and the volume-flow control element, in order to determine a control difference for the volume-flow adjustment of the volume-flow control element from the control deviation ascertained by the comparator in the case of the pressure in the high-pressure store, wherein in the range of a small control deviation, a characteristic with non-linear sections between the control deviation and the control difference is set for the volume-flow adjustment.

In accordance with the invention, a high-pressure

control element and a volume-flow control element as the two final control elements in a fuel-injection system are regulated directly on the basis of a control deviation that has been established between an actual-pressure value detected in the high-pressure store and a predetermined desired-pressure value. In this connection, in the range of small control deviations are used characteristics having non-linear sections between the control deviation which has been established and the control difference in the case of the volume flow delivered by the high-pressure pump that is to be compensated by way of the volume-flow control element, or between the control deviation which has been established and the control difference in the case of the pressure in the high-pressure store that is to be compensated by way of the high-pressure control element. As a result of the invention, it is possible to carry out by way of the detection of the pressure in the high-pressure store as single measured variable a direct regulation of both final control elements, so that both the volume-flow control element and the high-pressure control element have to be opened only to a minimum extent and in this way a particularly favourable energy balance is set. Preferred embodiments of the invention are presented in the dependent claims.

For a better understanding of the present invention, and to show how it may be brought into effect, reference will now be made, by way of example, to the accompanying drawings, in which:

Figure 1 shows a diagrammatic representation of a fuel-injection system;

Figure 2 shows a block-circuit diagram of a pressure regulation in accordance with the invention in a fuel-injection system;

Figure 3 shows a characteristic of a volume-flow

regulator in accordance with the invention; and

Figure 4 shows a characteristic of a high-pressure regulator in accordance with the invention.

Figure 1 shows diagrammatically the structure of a fuel-injection system, as used under the name Common-Rail-system in diesel engines and under the name High-Pressure-Direct-Injection-system in Otto engines. In this fuel-injection system, fuel is drawn in from a fuel storage tank 10 via a fuel line 11 by means of a forward delivery pump 12 and is conveyed by the latter, via a fuel filter 13, to a high-pressure pump 15. The high-pressure pump 15 then feeds the fuel under high pressure into a high-pressure store 17.

The high-pressure store 17 is connected to injection valves 18, by way of which the fuel is injected into the combustion chambers of the internal combustion engine (not shown). The injection process is triggered by an electronic control unit 19, which is connected by way of signal lines 20 to the injection valves 18. A leakage flow which occurs in the injection valves 18 is supplied by way of a fuel line 21 into the fuel storage tank 10. In order that the volume flow delivered by the high-pressure pump 15 into the high-pressure store 17 may be adjusted according to need in accordance with the operating condition of the internal combustion engine that is desired in each case, there is arranged in the fuel line 11, between the forward delivery pump 12 and the high-pressure pump 15, a suction regulating valve 14, which is driven by the electronic control unit 19 by way of a control line 22, in order to regulate the delivery flow of the high-pressure pump according to need.

For a pressure regulation in the high-pressure store 17 in accordance with the desired operating condition of the internal combustion engine, there is furthermore arranged in the fuel line 11, between the

high-pressure pump 15 and the high-pressure store 17, a
high-pressure control valve 16. This high-pressure
control valve 16 diverts surplus fuel, which is not
required in order to maintain the desired pressure in
5   the high-pressure store 17, back into the fuel storage
tank 10 by way of a fuel line 25. In this connection,
the high-pressure control valve 16 is adjusted by the
electronic control unit 19 by way of a signal line 24.

The adjustment of the suction regulating valve 14
10   and the high-pressure control valve 16 is carried out
by a regulating unit 190 of the electronic control unit
19 with the aid of an actual-pressure value in the
high-pressure store 17 that is determined by a pressure
sensor 23. The pressure prevailing in the high-
15   pressure store 17 is, as the block-circuit diagram in
Figure 2 shows, determined by the fuel amount contained
in the high-pressure store 17. This fuel amount is
made up of the fuel delivery flow of the high-pressure
pump 15 that is adjusted by the suction regulating
20   valve 14, the injection amount output during the
injection by way of the injection valves 18, the
leakage flow flowing off by way of the injection valves
18, and the fuel flow diverted by way of the high-
pressure control valve 16, with both the leakage flow
25   of the injection valves 18 and the fuel amount diverted
by way of the high-pressure control valve 16 depending
on the fuel pressure prevailing in the high-pressure
store 17.

In order to adjust the suction regulating valve 14
30   and the high-pressure control valve 16, the regulating
unit 190 of the electronic control valve 19 has a
comparator 191, which compares the actual-pressure
value detected in the high-pressure store 17 with the
aid of the pressure sensor 23 with a desired-pressure
35   value and determines a control deviation from the
difference between desired-pressure value and actual-

pressure value. The comparator 191 takes the desired-pressure value from a memory device (not shown) designed as a one-dimensional or multi-dimensional data field, in accordance with the specified operating

5 condition of the internal combustion engine, in particular the load and speed thereof. The regulating unit 190 further has as components of a first control loop a volume-flow regulator 192 and a first PI controller 193, which are arranged between the

10 comparator 191 and the suction regulating valve 14. As components of a second control loop, the regulating unit 190 also contains a high-pressure regulator 194 connected to the comparator 191 and a second PI controller 195 connected thereto, which is connected to

15 the high-pressure control valve 16.

In the volume-flow regulator 192, there is established from the control deviation between desired-pressure value and actual-pressure value ascertained in the comparator 191, with the aid of a predetermined

20 characteristic, a control difference, from which the first PI controller 193 determines a manipulated variable for the suction regulating valve 14 and outputs said manipulated variable as a control signal to an actuating drive in this valve, in order to adjust

25 the volume flow drawn in by the high-pressure pump 15 in accordance with the desired operating condition of the internal combustion engine.

In parallel with this adjustment of the suction regulating valve 14, the high-pressure regulator 194

30 determines, with the aid of a predetermined characteristic, from the control deviation ascertained by the comparator 191 a control difference for the pressure in the high-pressure store 17, from which control difference the second PI controller 195 forms a

35 manipulated variable for the high-pressure control valve 16 and outputs it as a control signal to an

actuating drive in this valve, in order thus to adjust the pressure in the high-pressure store 17 to the value which corresponds to the desired operating condition in the internal combustion engine.

As a result of the regulation in accordance with the invention, it is possible to adjust both the volume flow into the high-pressure store 17 and the pressure in the high-pressure store 17 separately by way of two control loops, but only one physical variable, namely the pressure in the high-pressure store, has to be detected in order to do this. As a result of the use of a separate control loop for the volume-flow adjustment, there can also be achieved a particularly favourable energy balance in the fuel-injection system, because in both valves the optimal valve setting, i.e. a minimum opening cross-section in the case of the suction regulating valve 14 and a minimum opening cross-section in the case of the high-pressure valve 16, can always be set.

In order to be able to stop at the valve position for the respective operating condition of the internal combustion engine that is most favourable in terms of energy quickly and with great control accuracy, the transfer characteristics of both the volume-flow regulator 192 and the high-pressure regulator 194 have non-linear sections in the range of small control deviations. Figure 3 shows such an exemplary optimised transfer characteristic of the control difference output to the first PI controller 193, with respect to the control deviation for the volume-flow regulator 192 that is ascertained by the comparator 191. Analogous hereto, Figure 4 shows an exemplary optimised transfer characteristic of the control difference output to the second PI controller 195, with respect to the control deviation for the high-pressure regulator 194 that is ascertained by the comparator 191.

As is evident from Figures 3 and 4, the control differences output by the volume-flow regulator 192 and the high-pressure regulator 194 to the PI controllers 193, 195 are always equated with the control deviation

5 between the desired-pressure value and the measured actual-pressure value that is ascertained by the comparator 191, with the exception of a symmetrical range ± delta about a control deviation zero. In this connection, the value for delta is preferably in a

10 control deviation range to a maximum of 0.5 MPa. In this range of small control deviation, non-linear sections are provided both in the characteristic of the volume-flow regulator 192 and in the characteristic of the high-pressure regulator 194 in order to prevent the

15 control, on the basis of the smallest control deviations that are still present, adjusting the valve settings in directions which are undesirable and unfavourable in terms of energy if the valves are basically already in their optimal position which is

20 most favourable in terms of energy. Thus, if the suction regulating valve 14 is already substantially closed, the control can, because of a small positive control deviation in the pressure in the high-pressure store 17, for example, attempt further to reduce the

25 volume flow by closing the suction regulating valve 14, as a result of which the suction regulating valve 14 is then completely closed and the fuel delivery is therefore interrupted. In order to prevent the two valves, as a result of the integration of the PI

30 controllers, leaving their optimal settings despite only the smallest control deviation, characteristic curves for the volume-flow regulator 192 and the high-pressure regulator 194 in the range of a control deviation ± delta about a control deviation zero are

35 chosen, as shown in Figures 3 and 4.

As Figure 3 shows, in the range of a control

deviation - delta to - delta + X, a control deviation which indicates a minimum to high pressure in the high-pressure store 17 is not perceived by the volume-flow regulator 192, so that there is no further adjustment of the suction regulating valve 14. In this connection, the range - delta to - delta + X advantageously extends from 0.5 MPa to 0.25 MPa. If, on the other hand, the control deviation is in the range zero to - delta + X, the characteristic of the control difference with respect to the control deviation in the volume-flow regulator 192 has an over-proportional increase, which is preferably between 2 and 4, so that the first PI controller 193 connected to the volume-flow regulator 192 reacts extremely strongly and specifies for the suction regulating valve 14 a manipulated variable which actively brings the control deviation into the range from zero to + delta, which corresponds to a pressure which is slightly too low with respect to the predetermined desired pressure. The range of small control deviation from zero to + delta, on the other hand, is not perceived by the volume-flow regulator 192, so that there is no further adjustment of the suction regulating valve 14.

In this dead zone in the case of a control deviation from zero to + delta, a regulation is not carried out by the high-pressure regulator 194 either, as Figure 4 shows, so that there is no unwanted integration by the second PI controller 195. The range of a control deviation from - delta to zero in which, as Figure 3 shows, the volume-flow regulator 192 has a dead zone is, on the other hand, as shown in Figure 4, used by the high-pressure regulator 194 in order to stop at the optimal valve position of the high-pressure control valve 16 with the aid of the second PI controller 195.

Claims

1. Method for regulating a pressure in a high-pressure store, which is supplied with a volume flow by a high-pressure pump, wherein the volume flow output by the high-pressure pump to the high-pressure store and the pressure in the high-pressure store are adjusted, comprising the steps of:

determining a control deviation between an actual-pressure value detected in the high-pressure store and a predetermined desired-pressure value;

determining a control difference for a pressure adjustment in the high-pressure store from the control deviation which has been ascertained in the case of the pressure in the high-pressure store, wherein in the range of a small control deviation, a characteristic with non-linear sections between the control deviation and the control difference is set for the pressure adjustment; and

determining a control difference for the volume-flow adjustment of the high-pressure pump from the control deviation which has been ascertained in the case of the pressure in the high-pressure store, wherein in the range of a small control deviation, a characteristic with non-linear sections between the control deviation and the control difference is set for the volume-flow adjustment.

2. Method according to claim 1, wherein the range of a small control deviation covers a difference between the actual-pressure value detected in the high-pressure store and the predetermined desired-pressure value around ± delta and wherein the value for delta preferably lies in the range up to a maximum 0.5 MPa.

3. Method according to claim 2, wherein the control difference for the volume-flow adjustment in the range of the control deviation from - delta to - delta + X is set at the value zero, is set over-

proportionally with respect to the control deviation in the range - delta + X to zero, and in the range zero to + delta is set at the value zero, wherein - delta + X preferably lies in the range up to 0.25 MPa.

4. Method according to claim 3, wherein the proportionality factor in the over-proportional range of the characteristic lies in the range from 2 to 4.

5. Method according to one of claims 2 to 4, wherein the control difference for the pressure adjustment in the range of the difference from - delta to zero is set proportionally with respect to the control deviation and in the range from zero to + delta is set at the value zero.

6. A method for regulating a pressure in a high-pressure store substantially as herein described, with reference to the accompanying drawings.

7. Arrangement for regulating a pressure in a high-pressure store, which is supplied with a volume flow by a high-pressure pump, comprising

a volume-flow control element for adjusting the volume flow output by the high-pressure pump to the high-pressure store; and

a high-pressure control element for adjusting the pressure in the high-pressure store; and

a control device which has: a comparator for determining a control deviation between an actual-pressure value detected in the high-pressure store and a predetermined desired-pressure value;

a high-pressure regulator, which is connected to the comparator and the high-pressure control element, in order to determine a control difference for the pressure adjustment of the high-pressure control element from the control deviation ascertained by the comparator in the case of the pressure in the high-pressure store, wherein in the range of a small control deviation, a characteristic with non-linear sections

between the control deviation and the control difference is set for the pressure adjustment; and

a volume-flow regulator, which is connected to the comparator and the volume-flow control element, in
5   order to determine a control difference for the volume-flow adjustment of the volume-flow control element from the control deviation ascertained by the comparator in the case of the pressure in the high-pressure store, wherein in the range of a small control deviation, a
10 characteristic with non-linear sections between the control deviation and the control difference is set for the volume-flow adjustment.

8.   Arrangement according to claim 7, wherein the volume-flow control element is a suction regulating
15 valve arranged upstream of the high-pressure pump, and the control device comprises a first PI-controller for adjusting the suction regulating valve.

9.   Arrangement according to claim 7 or 8, wherein the high-pressure control element is a high-pressure
20 control valve connected to the high-pressure store, and the control device comprises a second PI-controller for adjusting the high-pressure control valve.

10.   An arrangement for regulating the pressure in a high-pressure store substantially as herein
25 described, with reference to the accompanying drawings.

11.   A motor vehicle having an internal combustion engine having a high pressure fuel store regulated in accordance with the method as claimed in one of claims 1-6, or regulated by the arrangement as claimed in one
30 of claims 7-10.

The Patent Office

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Search Report under Section 17

Databases searched:

UK Patent Office collections, including GB, EP, WO & US patent specifications, in:

UK Cl (Ed.Q): G3R RAF, RBF, RBU.

Int Cl (Ed.6): F02D 41/38;   G05D 16/20.

Other: ONLINE: EPODOC, JAPIO, WPI.

Documents considered to be relevant:

Category	Identity of document and relevant passage		Relevant to claims
A	GB 2,328,526 A	(ROBERT BOSCH GMBH)	
A	US 5,727,515	(ROBERT BOSCH GMBH)	
A	US 5,720,262	(FIAT RICERCHE)	

X	Document indicating lack of novelty or inventive step	A	Document indicating technological background and/or state of the art.
Y	Document indicating lack of inventive step if combined with one or more other documents of same category.	P	Document published on or after the declared priority date but before the filing date of this invention.
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